Summing Amplifier (Summer or Adder)

Inverting Summing Amplifier

In this circuit, the input signals to be added are applied to the inverting input terminal.

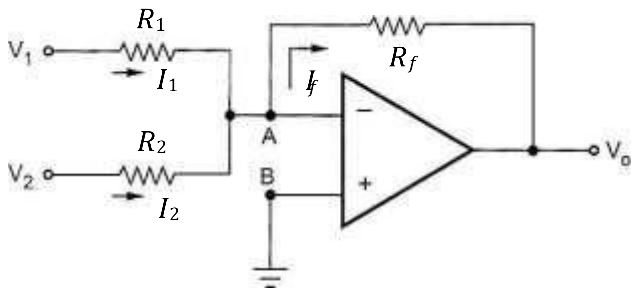

Fig. 18 Inverting summing amplifier (adder) with two inputs

An adder with two inputs is shown in Fig. 18.

From the circuit, the potential at node B, $V_B = 0$.

From the concept of virtual ground, the two input terminals are at same potential. Therefore, the potential at node A, $V_A = V_B = 0$.

From the circuit,

$$I_1 = \frac{V_1 - V_A}{R_1} = \frac{V_1 - 0}{R_1} \qquad (\because V_A = 0)$$

$$\boldsymbol{I_1 = \frac{V_1}{R_1}}$$

Similarly,

$$I_2 = \frac{V_2 - V_A}{R_2} = \frac{V_2 - 0}{R_2}$$

$$\boldsymbol{I_2 = \frac{V_2}{R_2}}$$

and

$$I_f = \frac{V_A - V_o}{R_f} = \frac{0 - V_o}{R_f}$$

$$\boldsymbol{I_f = -\frac{V_o}{R_f}}$$

Now since op-amp input current is zero, I_1 and I_2 together pass through R_f as I_f. That is,

$$I_f = I_1 + I_2$$

$$-\frac{V_o}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$$

$$V_o = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right)$$

$$\boxed{V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2\right)}$$

If $R_1 = R_2 = R$,

$$V_o = -\frac{R_f}{R}(V_1 + V_2)$$

If $R_1 = R_2 = R_f$,

$$\boxed{V_o = -(V_1 + V_2)}$$

This shows that the output is the sum of the input signals. The negative sign indicates that the phase is inverted.

Three-Input Adder (Inverting Summing Amplifier)

An adder with three inputs is shown in Fig. 19.

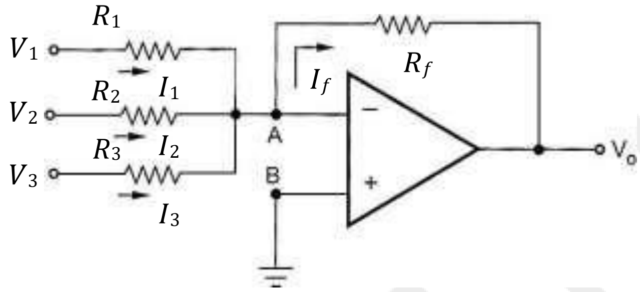

Fig. 19 Inverting summing amplifier (adder) with three inputs

From the circuit, the potential at node B, $V_B = 0$.

From the concept of virtual ground, the two input terminals are at same potential. Therefore, the potential at node A, $V_A = V_B = 0$.

From the circuit,

$$I_1 = \frac{V_1 - V_A}{R_1} = \frac{V_1 - 0}{R_1} \qquad (\because V_A = 0)$$

$$\boldsymbol{I_1 = \frac{V_1}{R_1}}$$

Similarly,

$$I_2 = \frac{V_2 - V_A}{R_2} = \frac{V_2 - 0}{R_2}$$

$$\boldsymbol{I_2 = \frac{V_2}{R_2}}$$

Also

$$I_3 = \frac{V_3 - V_A}{R_3} = \frac{V_3 - 0}{R_3}$$

$$\boldsymbol{I_3 = \frac{V_3}{R_3}}$$

and

$$I_f = \frac{V_A - V_o}{R_f} = \frac{0 - V_o}{R_f}$$

$$I_f = -\frac{V_o}{R_f}$$

Now since op-amp input current is zero, I_1, I_2 and I_3 together pass through R_f as I_f. That is,

$$I_f = I_1 + I_2 + I_3$$

$$-\frac{V_o}{R_f} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

$$V_o = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

$$\boxed{V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)}$$

If $R_1 = R_2 = R_3 = R$,

$$V_o = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

If $R_1 = R_2 = R_3 = R_f$,

$$V_o = -(V_1 + V_2 + V_3)$$

This shows that the output is the sum of the inputsignals. The negative sign indicates that the phase is inverted.

Non-Inverting Summing Amplifier

In this circuit, the input signals to be added are applied to the non-inverting input terminal. Fig. 20 shows a non-inverting summing amplifier with two inputs.

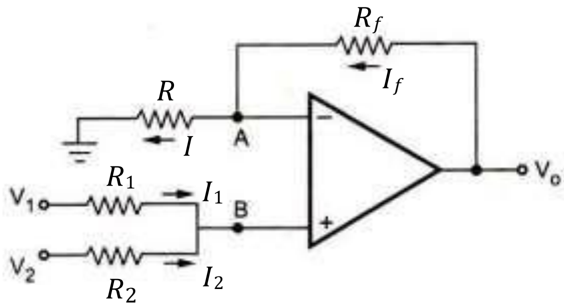

Fig. 20 Non-inverting summing amplifier

Let the potential at node B be V_B.

From the concept of virtual ground, the two input terminals are at same potential. Therefore, the potential at node A, $V_A = V_B$.

From the circuit,

$$I_1 = \frac{V_1 - V_B}{R_1}$$

and

$$I_2 = \frac{V_2 - V_B}{R_2}$$

Now since op-amp input current is zero,

$$I_1 + I_2 = 0$$

$$\therefore \frac{V_1 - V_B}{R_1} + \frac{V_2 - V_B}{R_2} = 0$$

$$\frac{V_1}{R_1} - \frac{V_B}{R_1} + \frac{V_2}{R_2} - \frac{V_B}{R_2} = 0$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = \frac{V_B}{R_1} + \frac{V_B}{R_2}$$

$$\frac{R_2V_1 + R_1V_2}{R_1R_2} = V_B\left(\frac{R_1 + R_2}{R_1R_2}\right)$$

$$V_B = \frac{R_2V_1 + R_1V_2}{R_1 + R_2} \tag{1}$$

At node A,

$$I = \frac{V_A}{R} = \frac{V_B}{R} \qquad (\because V_A = V_B)$$

and

$$I_f = \frac{V_o - V_A}{R_f} = \frac{V_o - V_B}{R_f}$$

Now since op-amp input current is zero,

$$I = I_f$$

$$\frac{V_B}{R} = \frac{V_o - V_B}{R_f}$$

$$\frac{V_B}{R} = \frac{V_o}{R_f} - \frac{V_B}{R_f}$$

$$\frac{V_o}{R_f} = \frac{V_B}{R} + \frac{V_B}{R_f}$$

$$\frac{V_o}{R_f} = V_B\left(\frac{R + R_f}{RR_f}\right)$$

$$V_o = V_B\left(\frac{R + R_f}{R}\right) \tag{2}$$

Substituting Eqn. (1) in (2),

$$V_o = \left(\frac{R_2V_1 + R_1V_2}{R_1 + R_2}\right)\left(\frac{R + R_f}{R}\right)$$

$$\boxed{V_o = \frac{R_2(R + R_f)}{R(R_1 + R_2)}V_1 + \frac{R_1(R + R_f)}{R(R_1 + R_2)}V_2}$$

If $R_1 = R_2 = R$,

$$V_o = \frac{R + R_f}{2R}(V_1 + V_2)$$

If $R_1 = R_2 = R = R_f$,

$$\boxed{V_o = V_1 + V_2}$$

This shows that the output is the sum of the input signals.